Solar Flares

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A solar flare is an explosion in a strongly magnetic region of the solar atmosphere—a violent burst of bulk mass motion, plasma particle energization, and radiation. Large solar flares are the greatest explosions in the solar system, blasting out through the solar wind, disrupting the magnetospheres of planets, and sweeping to the outer reaches of the heliosphere. From the observed strength and sheared structure of the magnetic field at flare sites, it is quite certain that the energy released in flares comes from the magnetic field, i.e., that flares are magnetic explosions. The basic questions posed by flares are: how does the magnetic field explode and how does the explosion produce the observed massive energization of electrons and ions to hard x-ray energies and beyond?

Flares often occur in complex magnetic field configurations made up of multiple impacted bipoles, each with its own polarity inversion. In these cases, the coronal loops and chromospheric ribbons that brighten in the flare have a correspondingly complex morphology. However, in some flares practically all of the energy release occurs within a magnetic field that bridges only a single inversion line, so that the arrangement of loops and ribbons is simpler: a single arcade of coronal flare loops bridges the single inversion line and is rooted in a pair of flare ribbons that bracket this inversion line. This general class of single-bipole flares includes a subclass known as "two-ribbon eruptive flares;" the largest and most powerful flares are usually of this type.

Solar scientists at MSFC recently proposed that the bulk dissipation of the magnetic field required for the electron energization for the hard x-ray emission in the explosive phase of flares occurs in a "fat current sheet"—a wall of cascading magneto-hydrodynamic turbulence sustained by highly disordered, driven reconnection of opposing magnetic fields impacting at a turbulent boundary layer.[1] In two-ribbon eruptive flares, this turbulent reconnection wall develops at the usual reconnection site in the standard model for these flares; i.e., the reconnection wall stands in the vertical magnetic rent made by the eruption of the sheared core of the preflare closed bipolar field.

During the past year, MSFC solar scientists, in collaboration with solar scientists at Goddard Space Flight Center, used the well-observed great two-ribbon eruptive flare of April 24–25, 1984, to assess the feasibility of both the standard model for the overall three-dimensional form and action of the magnetic field, as well as the turbulent reconnection wall within it.[2] The observed aspects of this flare that were used included the preflare photospheric vector magnetic field (observed with the MSFC vector magnetograph); the occurrence of a flare spray and the size, form, and spreading of the chromospheric flare ribbons (fig. 24); and the rate of production of hard x rays in the explosive phase of the flare (observed by Goddard's hard x-ray burst spectrometer on the Solar Maximum Mission). Researchers found that: (1) the morphology of this flare closely

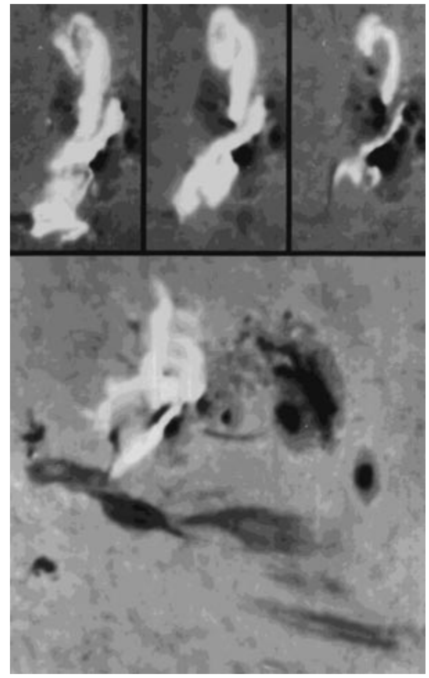

FIGURE 24.—Spreading of chromospheric flare ribbons.

matched that of the standard model; (2) the preflare sheared-core field had enough stored magnetic energy to power the flare; (3) the model turbulent wall required to achieve the flare's peak dissipative power easily fit within the flaring magnetic field; (4) this wall was thick enough to have turbulent eddies large enough (diameters on the order of 10^8 centimeters) to produce the energy-release fragments (of order 10^{26} ergs) typically observed in the explosive phase of flares; and (5) the aspect ratio of the reconnection wall was in the 0.1-to-1 range predicted by Parker.[3] In view of these observations, researchers therefore concluded that the viability of their version of the standard model (i.e., having the magnetic field dissipation occur in a turbulent reconnection wall) is well confirmed by this typical great two-ribbon flare.

[1]LaRosa, T.N., and Moore, R.L. 1993. A Mechanism for Bulk Energization in the Impulsive Phase of Solar flares: Magnetohydrodynamic Turbulent Cascade. *Astrophysical Journal*, 418, 912.

[2]Moore, R.L.; LaRosa, T.N.; and Orwig, L.E. 1995. The Wall of Reconnection-Driven Magnetohydrodynamic Turbulence in a Large Solar Flare. *Astrophysical Journal*, 438, 985.

[3]Parker, E.N. 1973. The Reconnection Rate of Magnetic Fields. *Astrophysical Journal*, 180, 247.

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